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Biographical Summary

Hui-Hai Liu is a staff scientist and currently serves as the head of Hydrogeology Department. He got his Ph.D. degree in soil physics (vadose zone hydrology) from Auburn University in 1995 and joined LBNL in 1997 as a geological scientist. His research interests include fracture hydrology, coupled hydrological and mechanical processes, vadose zone flow and transport, and their applications in geothermal energy, nuclear waste management and CO2 geological sequestration.

Education:

Ph.D. in Soil Physics, Auburn University, August 1995.
Dissertation title: An experimental and numerical study on fingering flow and mixing of variable density contaminants in porous media.

M.S. in Fluid Engineering, Huazhong University of Science and Technology, China, 1986. Thesis title: An improved singularity method to describe water flow in hydraulic turbines.

B.S. in Hydraulic Machinery, Beijing Agricultural Engineering University, China, 1983.

Honors
Fellow, Geological Society of America, 2007.
Outstanding Performance Award, LBNL, 2000; 2007.
Recognition of Commitment to Performance Excellence, U.S. Department of Energy CRWMS. 2004.
Emil Truog Soil Science Award for the Best Ph.D. Thesis. Soil Science Society of America, 1996.
Dr. A. L. Smith Award for the best Ph.D. candidate in soil sciences, Auburn University, 1994.

Work Experience

2009-present, Head, Department of Hydrogeology, Earth Sciences Division, Ernest Orlando Lawrence Berkeley National Laboratory.

1997-present, *Research Scientist* (1997-2000), *Career Research Scientist* (2001-2003), *Career Staff Scientist* (2004-present), Ernest Orlando Lawrence Berkeley National Laboratory.

1995-1997, *Research Assistant Professor* in the Dept. of Environmental System Engineering, Clemson University.

1991-1995, *GRA* in the Dept. of Agronomy & Soils, Auburn University.

1986-1991, *lecturer* in the Institute of Fluid Engineering and Machinery, Beijing Agricultural Engineering University.

Research Highlights

Fingering flow and mixing of variable density contaminants in porous media.
Collaborator: Dr. Jacob H. Dane, Auburn University
Density variability occurs in many subsurface-contaminant transport problems. Our major contributions in this area include developing and validating criteria for gravitational instabilities, experimentally revealing different unstable behavior of variable density contaminants, and developing numerical approaches for dealing with the unstable contaminant transport processes. My Ph.D. thesis documenting these contributions was selected as the best Ph.D. thesis of the year by Soil Science Society of America.

Fractal-Based characterization and simulation of subsurface heterogeneity.
Collaborator: Dr. Fred J. Molz, Clemson University
Subsurface heterogeneity and its effect on subsurface contaminant transport have been key research topics for many years. Our major contributions in this area include for the first time reporting the multifractal behavior of permeability distributions, demonstrating the Levy-fractal behavior of permeability distributions in fractured rock, revealing the scale-dependency of Levy index when using Levy fractals for characterizing subsurface heterogeneity, and also developing a number of fractal-based approaches for characterizing and modeling subsurface heterogeneity. These contributions have been very well received in the subsurface hydrology community.

Flow and transport in unsaturated fractured rock.
Collaborator: Scientists at LBNL
Flow and transport in unsaturated fractured rock is an important issue for both subsurface contaminant transport and geological disposal of nuclear wastes, and also one of the most challenging research topics in the subsurface hydrology. Our major contributions in this area include developing new constitutive relations for fracture networks, proposing a new upscaling method of constitutive relations for unsaturated tuff matrix, and extending random walk particle methods from a single continuum to dual-continua. Especially, we developed an active fracture model for describing preferential flow, and theoretically demonstrated the consistency of the model with fractal flow patterns often observed in unsaturated systems. While how to model flow and transport in unsaturated fractured rock remains an issue of current debate, the active fracture model has been one of the most widely used models in this area. U.S. Department of Energy has also used

it as a primary model for modeling flow and transport in the unsaturated zone of Yucca Mountain, Nevada, the proposed location for a nuclear waste repository in the United States.

Matrix diffusion and scale-dependency of the effective matrix diffusion coefficient.
Collaborator: Scientists at LBNL; Dr. Fred J. Molz at Clemson University
Matrix diffusion has been a classic research topic in fracture hydrology because of its importance for retarding solute transport. We for the first time reported the potential scale-dependency of the effective matrix diffusion coefficient, which has significant implications for understanding and modeling contaminant transport processes in fractured rocks.

Coupled hydrological and mechanical processes in the subsurface.
Collaborator: Scientists at LBNL (Drs. Jonny Rutqvist and James G. Berryman)
Coupled hydrological and mechanical processes are important for many practical applications including nuclear waste disposal and CO_2 geological sequestration. My contribution in this area is the development of a general relationship between stress and elastic strain for porous and fractured rock, based on a hypothesis that a natural rock consists of "hard" and "soft" parts and different parts follow different varieties of Hooke's law. This development allows for unifying a large number of empirical relationships between stress and mechanical properties within a rather simple theoretical framework. Modeling large-scale coupled hydrological and mechanical processes is currently a major research activity in this area.

Professional membership:

    American Geophysical Union
    Soil Science Society of America.
    Geological Society of America
    American Rock Mechanics Association

Selected Professional Activities
Associate Editor, Hydrogeology Journal (2006-present)
Liaison for National Soil Science Committee, Geological Society of America (2006-2009)
Guest Editor, Vadose Zone Journal, (2006-2007).
Member, Emil Truog Soil Science Award committee, Soil Science Society of America (2003-2005)

Publications:

A. Journal Articles:

1. Liu, Hui-Hai and J.H. Dane, Reconciliation between measured and theoretical temperature effects on soil water retention curves. Soil Science Society of America Journal, 57, 1202-1207, 1993.

2. Johnsen, K.E., Liu Hui-Hai, J.H. Dane, L.R. Ahuja and S.R. Workman, Simulating fluctuating water tables and tile drainage with the Root Zone Water Quality model and a new model WAFLOWM. Transaction of American Society of Agricultural Engineers, 38: 75-83, 1995.

3. Liu, Hui-Hai, J.H. Dane and O. Güven, An adaptive modified method of characteristics for the one-dimensional solute transport equation. Soil Science Society of America Journal, 59:677- 683, 1995.

4. Liu, Hui-Hai and J.H. Dane, Improved accuracy in the determination of capillary pressure head-volumetric fluid content relations for immiscible fluids using pressure cells. Soil Science Society of America Journal, 59:1520-1524,1995.

5. Liu, Hui-Hai and J.H. Dane, An interpolation-corrected modified method of characteristics to solve advection dispersion equations. Advances in Water Resources, 19(6), 359-368, 1996.

6. Liu, Hui-Hai and J.H. Dane, Use of two approaches to model unstable flow and mixing of variable density fluids in porous media. Transport in Porous Media, 23(2): 219-236,1996.

7. Liu, Hui-Hai and J. H. Dane, A Criterion for gravitational instabilities in miscible dense plumes. Journal of Contaminant Hydrology, 23, 233-243, 1996.

8. Liu, Hui-Hai and J.H. Dane, An extended transfer function model of field-scale solute transport through unsaturated zone. Soil Science Society of America Journal. 60:986-991, 1996.

9. Liu, Hui-Hai and J.H. Dane, A numerical model study on unstable flow and mixing of variable density fluids in three-dimensional layered porous media. Journal of Hydrology, 194: 126-142, 1996.

10. Molz, F.J. and Hui-Hai Liu, Fractional Brownian motion (fBm) and fractional Gaussian noise (fGn) in subsurface hydrology. Water Resources Research, 33(10), 2273-2286, 1997.

11. Liu, Hui-Hai and F. J. Molz, The discrimination of fBm/fGn structures in permeability and related property distributions with range analyses, Water Resources Research, 32(8), 2601-2605, 1996.

12. Liu, Hui-Hai and F. J. Molz, Comment on "Evidence for non-Gaussian scaling behavior in heterogeneous sedimentary formations" by Scott Painter, Water Resources Research, 33(4), 907-908, 1997.

13. Liu HH, Molz FJ, Boman GK, Correction of "Further evidence of fractal structure in hydraulic conductivity distributions", GEOPHYSICAL RESEARCH LETTERS 23 (16): 2201-2201 AUG 1 1996

14. Liu, Hui-Hai and F.J. Molz, Multifractal analyses of hydraulic conductivity distribution, Water Resources Research , 33(11), 2483-2488, 1997.

15. Liu, Hui-Hai and F.J. Molz, Block scale dispersivity for heterogeneous porous media characterized by stochastic fractals, Geophysics Research Letter, 24(17), 2239-2242, 1997.

16. Liu, Hui-Hai and F.J. Molz, Comment on "Scaling of random fields by means of truncated power variograms and associated spectra" by V. D. Federico and S P. Neuman, Water Resources Research 34(11), 3207-3208, 1998.

17. Liu, H.H., C. Doughty and G. S. Bodvarsson, An active fracture model for unsaturated flow and transport in fractured rocks, Water Resources Research, 34(10), 2633-2646, 1998.

18. Liu, H.H., G.S. Bodvarsson, Determination of particle transfer probability in random walk algorithms for fractured porous media, Water Resources Research, 36(3) 707-713, 2000.

19. Liu, H.H. and G.S. Bodvarsson, Constitutive relations for unsaturated flow in a fracture network, Journal of Hydrology, 252, 116-125, 2001.

20. Liu, H.H., G.S. Bodvarsson and S. Finsterle, A note on unsaturated flow in two-dimensional fracture networks. Water Resources Research, 38 (9), 1176, doi: 10.1029/2001WR000977, 2002.

21. Liu, H.H., G.S. Bodvarsson and L. Pan, Reply to Comment on "Determination of particle transfer in random walk particle methods for fractured porous media, Liu, Bodvarsson, Pan" by Hassan, Water Resources Research, 38(11), DOI 10.1029/2002WR001568, 2002.

22. Liu, H.H., C. Haukwa, F. Ahlers, G.S. Bodvarsson, Modeling flow and transport in unsaturated fractured porous media: An evaluation of the continuum approach, Journal of Contaminant Hydrology 62-63, 176-188, 2003.

23. Zhou, Q., H.H. Liu, G.S. Bodvarsson and C. Oldenburg, Unsaturated flow and transport in fractured rocks: Effects of multi-scale heterogeneities. Journal of Contaminant Hydrology, 60 (1), 1-30, 2003.

24. Lu, S., F. Molz and H.H. Liu, An efficient, three-dimensional, anisotropic, fractional Brownian motion and truncated fractional Levy motion simulation algorithm based on successive random additions, Computers and Geosciences, 29(1), 15-25, 2003.

25. Seol, Y., H.H. Liu and G.S. Bodvarsson, Effects of Dry Fractures on Matrix Diffusion in Unsaturated Fractured Rocks. Geophysical Research Letter, 30(2), 1075, doi:10.1029/2002GL016118, 2003.

26. Liu, H.H. and G.S. Bodvarsson, Upscaling of constitutive relations in unsaturated heterogeneous porous media with large air entry values, Journal of Hydrology, 276, 198-209, 2003.

27. Liu, H.H., G. Zhang and G.S. Bodvarsson, The active fracture model: Its relation to fractal flow behavior and a further evaluation using field observations, Vadose Zone Journal 2003 (2): 259-269.

28. Wu, Yu-Shu. Hui-Hai Liu and G.S. Bodvarsson, A triple-continuum model for investigating effects of small-scale fractures on flow and transport processes in fractured rocks. Journal of Contaminant Hydrology 2004 (73): 145-279.

29. Liu, H.H., G.S. Bodvarsson, and G. Zhang, The scale-dependency of the effective matrix diffusion coefficient, Vadose Zone Journal, 3: 312-315, 2004.

30. Liu, H.H., A constitutive-relationship model for film flow on rough fracture surfaces, Hydrogeology Journal 12:237-240, 2004.

31. Zhang, K., Y. S. Wu, G.S. Bodvarsson and H.H. Liu, Flow focusing in unsaturated fracture networks: A numerical investigation, Vadose Zone Journal, 3: 624-633, 2004.

32. Liu, H.H., G.S. Bodvarsson, F.J. Molz and S. Lu, A generalized successive random additions algorithm for simulating fractional Levy motion. Mathematical Geology, 36(3): 361-378. 2004.

33. Liu, H.H., R. Salve, J. S. Y. Wang, G. S. Bodvarsson, and D. Hudson, Field investigation into unsaturated flow and transport in a fault: Model analysis, Journal of Contaminant Hydrology, 2004 (74): 39-59.

34. Salve R., H.H. Liu, P. Cook, A. Czarnomski, Q. Hu and D. Hudson, Unsaturated flow and transport through a fault embedded in fractured welded tuff. Water Resources Research, 40 (W04210), doi: 10.1029/2003WR002571, 2004.

35. Salve R., H. H. Liu, J. S. Y. Wang and D. Hudson, Development of a wet plume following liquid release along a fault. Vadose Zone Journal, 4(1): 89-100, 2005.

36. Liu, H.H., R. Zhang and G.S. Bodvarsson, An active region model for capturing fractal flow patterns in unsaturated soils: Model development. Journal of Contaminant Hydrology, 74, 39-59, 2005.

37. Zhou Qualin, Hui-Hai Liu and Fred J. Molz, Evidence of Multi-Process Matrix Diffusion in a Single Fracture from a Field Tracer Test. Transport in Porous Media, 63, 473-487, 2006.

38. Zhang Y., H.H. Liu, Q. Zhou and S. Finsterle, Effects of dual-scale heterogeneity on effective matrix diffusion coefficient in fractured rocks, Water Resources Research, VOL. 42, W04405, doi:10.1029/2005WR004513, 2006.

39. Liu, H.H., G.S. Bodvarsson and J.H. Dane, Temperature Dependence of large-scale water retention curves: A case study, HYDROGEOLOGY JOURNAL 14 (8): 1403-1408 DEC 2006.

40. Zhou, Qualin, Rohit Salve, Hui-Hai Liu, Joseph Wang, and David Hudson, Analysis of a Mesoscale Infiltration and Water Seepage Test in Unsaturated Fractured Rock: Fracture-Informed Spatial Variability. JOURNAL OF CONTAMINANT HYDROLOGY 87 (1-2): 96-122 SEP 10 2006.

41. Wu, Y. S., K. Zhang and H.H. Liu, Estimating large-scale permeability of fractured rock using barometric pressure data. VADOSE ZONE JOURNAL 5 (4): 1129-1142 NOV 2006.

42. Liu H.H. Y.Q. Zhang, Q. Zhou and F. J. Molz, An Interpretation of Scale Dependence of Effective Matrix Diffusion Coefficient. JOURNAL OF CONTAMINANT HYDROLOGY 90 (1-2): 41-57 FEB 20 2007.

43. Zhou, Qualine, Hui-Hai Liu, Yinqi Zhang and Fred J. Molz, Effective matrix diffusion coefficient for fractured rock: Results from literature survey. JOURNAL OF CONTAMINANT HYDROLOGY 93 (1-4): 161-187 AUG 15 2007.

44. Liu, H.H., Y. Zhang and F. J. Molz, Scale Dependence of Effective Matrix Diffusion Coefficient: Some Analytical Results. VADOSE ZONE JOURNAL 6 (3): 679-683 AUG 2007

45. Liu, HH, Illangasekare , TH. Preface: Recent Advances in Modeling Multiphase Flow and Transport with the TOUGH Family of Codes. VADOSE ZONE JOURNAL Volume: 7 (1): 284-286 FEB 2008

46. Guan, J., F. J. Molz, Q. Zhou, H. H. Liu, and C. Zheng, Behavior of the mass transfer coefficient during the MADE-2 experiment: New insights, Water Resour. Res., 44, W02423, doi:10.1029/2007WR006120, 2008.

47. Liu, H.H., J. Rutqvist and J.G. Berryman, On the relationship between stress and elastic strain for porous and fractured rock. International Journal of Rock Mechanicals & Mining Science & Mining Sciences 46: 289-296, 2009.

48. Shen F., K. Wang, R.D. Zhang and H.H. Liu, Characterizing soil preferential flow using iodine-starch staining experiments and the active region model. Journal of Hydrology, 367(2):115-124, 2009.

49. Liu, H.H. and J. Rutqvist, Coupled hydro-mechanical process associated with multiphase flow in a dual-continuum system: Formulations and a sensitivity Study. (in review)

50. Liu, H.H. and J. Rutqvist, A new coal-permeability model: Internal swelling stress and fracture-matrix interaction. (in press) Transport in Porous Media

51. Liu, H.H. and R. Zhang, Macroscopic relationship for preferential flow in vadose zone: Theory and validation. Science in China, E:-Tech. Sci., 2009, 52(11): 3264-3269.

52. Liu, H.H., Comment on "Sensitivity of the active fracture model parameter to fracture network orientation and injection scenarios", Hydrogeology Journal (in press).

B. Book Chapters:

53. Mansell, R.S., J.H. Dane, D. Shinde, and H.H. Liu, 1997, Density-coupled water flow and contaminant transport in the vadose zone: An overview, Invited Chapter in ***Physical Nonequilibrium in soils: Modeling and application,*** edited by H. M. Selim, Ann Arbor press.

54. Dane, J.H., C. Hofstee, M. Oostrom, H.H. Liu and A. T. Corey, 1999, Determination of Capillary pressure-Saturation-permeability relations for nonwetting fluids in water wet porous media, in ***Characterization and Measurement of the Hydraulic Properties of Unsaturated Porous Media,*** edited by van Genuchten, M., F.J. Leij and L. Wu, published by University of California, Riverside.

55. Bodvarsson, G.S., S. Finsterle, H.H. Liu, C.M. Oldenburg, K. Pruess, E. Sonnenthal and Y.S. Wu, 2000, Flow and Transport Modeling of Subsurface Systems, in ***Vadose Zone Hydrology: Science and Technology Solutions.*** Edited by R.B. Looney and R.W. Falta, Battelle Press.

56. Bodvarsson, G.S., H.H. Liu, R. Ahlers, Y.S. Wu and E. Sonnethal, 2000. Parameterization and upscaling in modeling flow and transport at Yucca Mountain, in ***Conceptual Models of Unsaturated Flow in Fractured Rocks***, National Research Council.

57. Liu, H.H., J. Rutqvist, Q. Zhou and G.S. Bodvarsson, 2004. Upscaling of Normal stress-permeability relationships for fracture networks obeying the fractional Levy motion, in ***Coupled Thermo-Hydro-Mechanical-Chemical Processes in Geo-Systems: Fundamentals, Modeling, Experiments and Applications,*** Edited by Ove Stephansson, John A. Hudson and Lanru Jing, Elservier.

C. Conference Paper

58. Liu, H.H., Y. Zhang and J. Houseworth, A Modified Generalized Likelihood Uncertainty Estimation (GLUE) Methodology, *International High-Level Radioactive Waste Management Conference,* Las Vegas, Nevada, 2008

59. Liu, H.H., Y. Zhang and F. J. Molz, Scale Dependence of Effective Matrix Diffusion Coefficient: Evidence and Preliminary Interpretation, *International High-Level Radioactive Waste Management Conference,* Las Vegas, Nevada, 2006.

60. Liu, H.H., J. Rutqvist, Q. Zhou and G.S. Bodvarsson, Upscaling of Normal stress-permeability relationships for fracture networks obeying the fractional Levy motion, *GREPROC, International conference on coupled T-H-M-C processes in geosystems: Fundamentals, modeling, experiments and applications*, Stockholm, Sweden, 2003.

61. Wu, Y.S., H.H. Liu and Bodvarsson, Effects of small fractures on flow and transport processes at Yucca Mountain, Nevada, *International High-Level Radioactive Waste Management Conference,* Las Vegas, Nevada, 2003.

62. Zhang, K., Y.s. Wu, G.S. Bodvarsson and H.H. Liu, Determination of unsaturated flow paths in fracture networks, *World Water Environmental Resources Congress 2003,* Philadelphia, 2003.

63. Liu, H.H., G.S. Bodvarsson and D. Hudson, Large-scale constitutive relationships for unsaturated flow in fractured rocks. *International Groundwater Symposium*, Berkeley, 2002.

64. Zhou, Q., H.H. Liu, G.S. Bodvarsson and C. Oldenburg, Unsaturated flow and transport in fractured rocks. *International Groundwater Symposium*, Berkeley, 2002.

65. Liu, H.H. and G.S. Bodvarsson, Possible scale-dependency of effective matrix diffusion coefficient, 2nd international Symposium *Dynamics of Fluids in Fractured Rock,* Berkeley, California, 2004.

66. Liu, H.H., G. Zhang and G.S. Bodvarsson, The active fracture model, *TOUGH2 Symposium 2003,* Berkeley, California, 2003.

D. Major Research Report (Peer-Reviewed):

67. Liu, H.H., C.F. Ahlers and G. Zhang, *Analyses of Hydraulic Properties Data* (Rev 01), BSC Model Report, 2003.

68. Liu, H.H. and G.S. Bodvarsson, *Technical Basis Document N0. 2: Unsaturated Zone Flow*, BSC, 2004.

69. Liu, H.H., *Conceptual Model and numerical approaches for UZ flow and transport*, BSC, 2004.

70. Liu, H.H., G. P. Lu and R. Salve, *Analyses of Alcove 8/Niche 3 Flow and Transport Tests*, BSC Analysis Report, 2006.

71. Ahlers, C.F. and H.H. Liu, *Calibrated Properties Models*, (REV 00) CRWMS M&O, Analysis and Model Report, LBID-2325, 2000.

72. Moridis, G.J., Y. Seol, H.H. Liu, A. Meijer. 2003. *Radionuclide Transport Models Under Ambient Conditions*. MDL-NBS-HS-000008 REV01. Las Vegas, Nevada: Bechtel SAIC Company

73. Ahlers, C.F., Y.S. Wu. Q. Hu, P. Pan, H.H. Liu, G. Li, and J., Liu, *Unsaturated Zone Flow Patterns and Analysis,* BSC Model Report, 2001.

74. Wu, Y.S., Liu, J. Xu, T., Haukwa, C., Zhang, W., Liu, H.H. and Ahlers, C.F., 2000. **UZ flow models and submodels** (Rev. 00) *Report MDL-NBS-HS-000006,* Lawrence Berkeley National Laboratory, CRWMS M&O.

75. Pan, L., H.H. Liu and G.S. Bodvarsson, *DCPT: A New Random Walk Particle Tracker for Dual-Continuum*. Berkeley Lab Report LBNL-42958, 1999.

E. Other Research Report:

76. Liu, H.H., M. Cushey and C.F. Ahlers, *Analyses of Hydraulic Properties Data* (Rev 00), CRWMS M&O, Analysis and Model Report, LBID-2330, 2000.

77. Bodvarsson et al., *Unsaturated zone flow and transport model process model*, CRWMS M&O, Process Model Report, LBID-2337, 2000.

78. Liu, H.H. and C. F. Ahlers, *Calibrated Properties Models* (Rev 01), BSC Model Report, 2003.

79. Pan, L and H.H. Liu, *Analyses of Hydraulic Properties Data* (Rev 02), BSC Model Report, 2004.

80. Ghezzehei, T.A. and H.H. Liu, *Calibrated Properties Models* (Rev 02), BSC Model Report, 2004.

81. Wu et al., *Unsaturated Zone Model and Submodels* (Rev 02)*,* BSC Model Report, 2004.

82. Bodvarsson G.S., J.T. Birkholzer, S. Finsterle, H.H. Liu, J. Rutqvist, and Y.S. Wu, The use of Tough2/iTOUGH2 in support of the Yucca Mountain Project: Successes and Limitations. *TOUGH2 Symposium 2003,* Berkeley, California, 2003.

83. Wu, Y.S. ,C. Haukwa, J.J. Hinds, A.C. Ritcey, H.H. Liu, L.H. Pan, M. Cushey, W. Zhang, A.K. Mishra, E.L. Sonnenthal, and G.S. Bodvarsson, 1998, *Letter Report: PTn and CHn lateral flow model*. Level 4 Milestone SP3CKFM4.

84. Wu, Y.S., A.C. Ritcey, C.F. Ahlers, J.J. Hinds, A.K. Mishra, C. Haukwa, T.M. Bandurraga, H.H. Liu, E.L. Sonnenthal, and G.S. Bodvarsson, 1998, *A 3-D site-scale model for abstraction in TSPA-VA*. Level 4 Milestone SLX01LB3.

85. Liu, H.H., and G.S. Bodvarsson. 1998. "*A Fracture-Matrix Interaction Model*." In: G.S. Bodvarsson, E.L. Sonnenthal and Y.S. Wu. eds. Unsaturated Zone Flow and Transport Modeling of Yucca Mountain, Nevada—Fiscal Year 1998 Report, Chapter 8. Yucca Mountain Project Milestone SP3CKJM4. Berkeley, California: Lawrence Berkeley National Laboratory. Document ID# BAB000000-01717-2200-00016.

86. Liu, H.H., and G.S. Bodvarsson. 1998. "*UZ Model Property Set*." In: G.S. Bodvarsson, E.L. Sonnenthal, and Y.S. Wu, eds., Unsaturated Zone Flow and Transport Modeling of Yucca Mountain, Nevada —Fiscal Year 1998 Report, Chapter 9. Yucca Mountain Project Milestone SP3CKJM4. Berkeley, California: Lawrence Berkeley National Laboratory. Document ID# BAB000000-01717-2200-00016.

87. Liu, H.H. and J.H. Dane. 1995. *Computation of the Brooks-Corey parameters at a physical point based on pressure cell data*. Alabama Agricultural Experimental Station, Auburn University.

88. Jalbert M., J.H. Dane and H.H. Liu. 1999. *TrueCell: Phyical point Brooks-Corey parameters using pressure cell data*. Alabama Agricultural Experimental Station, Auburn University.

Invited Presentations:

1. Liu H.H., *Scale dependence of effective matrix diffusion coefficient in fractured rock.* Water Resources Seminar, U.S. Geological Survey, Menlo Park, California.

2. Liu et al., *Potential Scale Dependence of Effective Matrix Diffusion Coefficient,* Western Pacific Gophysics meeting of American Geophysical Union, Beijing, China, 2006.

3. Zhang Y. and H. H. Liu, *A Simplified Representation of Matrix Diffusion Effects Incorporating Diffusive Property Heterogeneity Using Particle Tracking,* Western Pacific Gophysics meeting of American Geophysical Union, Beijing, China, 2006.

4. Molz F., J. Guan, H.H. Liu and C. Zheng, *Field-Scale Hydraulic Conductivity and Mass Transfer at the MADE Site in Columbus, Mississippi: A review and Continuing Studies*, Fall meeting of American Geophysical Union, San Francisco, California, 2006.

5. Liu, H.H., *A fractal approach to simulate flow and transport in unsaturated soils.* China National Science Fundation, Beijing, 2005.

6. Liu, H.H., *Modeling flow and transport in unsaturated zone: Where are we?* China Agricultural University, Beijing, 2003.

7. Liu, H.H., G.S. Bodvarsson and J.H. Dane, *Effects of temperature on large-scale water retention curves: A case study.* Annual meeting of Soil Science Society of America, 2001.

8. Liu, H.H. and G.S. Bodvarsson, *The Use of Continuum Approach to Model Flow and Transport in Unsaturated Fractured Rocks: Recent Progress*. Fall meeting of American Geophysical Union, San Francisco, California, 2000.

9. Bodvarsson, G.S., H.H. Liu, J. Liu and Y.S. Wu, *Recent Modeling Study of Flow and Transport in the Unsaturated Zone of Yucca Mountain, Nevada*, Annual meeting of Geological Society of America, Reno, NV, 2000.

10. Molz, F. and H.H. Liu, *Characterization of Subsurface Heterogeneity: Theory and Application.* Fall meeting of American Geophysical Union, San Francisco, California, 1997.

11. Liu, H.H., *Unstable Variable Density Flow and Transport in the Subsurface: Numerical and Experimental Investigations.* University of South Carolina, SC., 1997.